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Theme Session on The Response of Cephalopod Populations and Fisheries to Changing Environment and Ecosystems (Session K)

Counting Cephalopods in the Census of Marine Life

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Abstract

The Census of Marine Life seeks to assess and explain diversity, distribution and abundance of life in the world's oceans through an international research program, quantifying organisms at species level using modern techniques. It is the first such program aimed at providing a baseline for the living elements of earth's largest habitat. It is creating an Ocean Biogeog aphic Information System (OBIS) dynamic database to capture Census output and display biodiversity and distribution data in relation to ocean physics. Currently, six pilot projects are calibrating techniques to be applied during the Census decade. The legacy of OBIS will be a powerful tool for solving problems and modeling future ecosystems. Although cephalopod biodiversity is not as high as many groups, their biomass is a major component of poorly studied ocean habitats. The Census will increase sampling intensity to reveal new species, quantify known ones and examine genetic variability. CephBase, one of the first OBIS components, is concentrating current knowledge of cephalopod distributions and will be key in documenting their roles in ecosystems. Cephalopod opportunities in pilot projects will be discussed.

1. Introduction

Although living cephalopods, as a class, show relatively low diversity globally, they are abundant in many large and poorly studied marine ecosystems. Thus, they are prime targets for the Census of Marine Life, which aims to improve our quantitative understanding of the diversity and distribution of marine life (Ausubel, 1999). The decade-long CoML (www.coml.org) will provide a benchmark for marine biodiversity at the beginning of the new millennium, based on broad application of modern sampling techniques, and store this information in an accessible Ocean Biogeographic Information System (OBIS) in which biological data can be overlaid on physical and chemical data (Grassle, 2000; marine.rutgers.edu/OBIS/). Departures from this benchmark will be important indicators of change in the state of the ocean in the future as climatic and fisheries management regimes change. Cephalopod fauna may be particularly important, given the evidence (Caddy and Rodhouse, 1998) that short-lived cephalopods tend to replace long-lived fishes when ecosystems are perturbed. The importance of cephalopods in this context was a major reason for the inclusion of CephBase as one of the prototype databases in OBIS (Wood *et al.*, 2000; www.cephbase.utmb.edu).

The Census of Marine Life seeks to assess and explain the diversity, distribution and abundance of life in the world's oceans. Crisis after crisis in ocean ecosystems has been documented from species removals, species introductions and environmental change. A global inventory of what lives in the oceans is a critical step toward dealing with these crises. Now is the time for a concerted effort as powerful new methods to census marine life converge with society's interest in exploring Earth's last frontier and need to use its resources wisely.

Marine biology started with collecting and cataloguing ocean life. The first step to understanding any system is describing what is in it and the second is quantifying it; both are essential before its interactions can be analysed. Basic biology learned much from the study of marine organisms, their development and their physiology. Biological oceanography developed as an interdisciplinary field of science that has contributed much understanding of biological productivity and the important role of ocean life in cycling key elements such as carbon and oxygen in the biosphere. This science has revealed, however, that ocean ecosystems are not simple chemical reactions: the composition and behaviour of the species involved in these elemental cycles and food chains matter greatly.

Therefore, unlike previous global oceanographic research programs, the Census of Marine Life will treat organisms as species rather than masses of carbon. It is necessary to know the diversity and composition of communities of organisms to understand how they cycle materials and produce organic matter, including the food humans harvest. This is particularly true for animals high on the food chain, which are both regulated by the food available to them and often regulate lower trophic levels. These species, including cephalopods, have been difficult to sample quantitatively, but sophisticated new technologies provide new opportunities.

Although it is estimated that a quarter of the fish species living in the ocean have not yet been discovered by science, it is also estimated that fishery stocks are presently fully or over-exploited. Recent analyses of global fisheries have revealed that as populations of fishes feeding high on the food chain are over-fished, fishing shifts to species lower on the food chain. Major restructuring of ocean ecosystems may result. Controversies rage over defining sustainable levels or restoration strategies for species as familiar as salmon, but we lack critical knowledge about migration patterns, feeding and abundance in the ocean.

2. Methods

Several major components of the CoML will contribute to our understanding of the role of cephalopods in marine ecosystems. The History of Marine Animal Populations (HMAP; www.cmrh.dk/hmapindx.html) will provide insights into the composition of 'pristine ecosystems' (Starkey *et al.*, 2000) in sites already impacted by human activities for comparison to the current status revealed by CoML field projects. The already well-studied Gulf of Maine will be re-examined (GoMe; www.whoi.edu/marinecensus/) by applications of advanced techniques such as remotely operated vehicles (ROVs) utilizing precision underwater navigation methods, detailed maps and differential GPS guided sampling with physical devices such as grabs and cores based on side-scan sonar maps of detailed sedimentary classification of the sea floor (Barnhardt *et al*., 1998). This project will include pelagic sampling and extend the techniques tested on the continental shelf out to a nearby seamount, likely providing opportunities for new cephalopod observations.

Ecosystems still believed to be relatively pristine will be examined by the Mid-Atlantic Ridge Ecosystem project (MAR-ECO; www.efan.no/midatlcensus/), focusing advanced acoustic and imaging technology on mesopelagic and benthic communities, and the Chemosynthetic Ecosystems project (ChEss), developing a comparative approach to seep and vent communities along a latitudinal gradient (Van Dover, 2000). Both of these ecosystems have been shown to contain surprising cephalopod fauna (Vecchione and Young, 1998; Voight *et al.*, 1999)

Protocols for documenting the biodiversity of coastal zones below 20 m, developed for the CoML under the DIVERSITAS in the Western Pacific, IBOY program (DIWPA; ecology.kyoto-u.ac.jp/~gaku/) can be replicated to provide detailed coverage of vast areas of coastline, which may include numerous new species of octopods (Norman and Sweeny, 1997). The DIWPA protocols are designed to be easily and cheaply reproduced and can be applied to any area of coastline in the world to provide uniform biodiversity coverage.

A census must also include mechanisms for adjusting for the mobility of the elements being quantified, and the CoML includes two demonstration projects focused on migratory species. The Tracking of Pacific Pelagics (TOPP) project will use archival tags and satellite telemetry (Block *et al.*, 2001) to monitor the movements of a variety of mega-fauna including albatrosses, elephant seals, tuna, salmon sharks and the jumbo squid *Dosidicus gigas*. The Pacific Ocean Salmon Tracking (POST) project uses monitoring lines to detect the passage of coded acoustic tags. Up to 256,000 different codes can be used on animals as small as salmon smolts (25 g), so that a wide variety of species can potentially be tracked by the same system of lines. Along the Pacific coast of North America the obvious cephalopod candidate is the market squid *Lologo opalescens*.

3. Results

As CephBase grows with the addition of databases it is becoming an increasingly powerful research tool. In addition to its value as an accessible taxonomic reference it includes an expanding collection of cephalopod images valuable for specimen recognition as well as public interest. Its mapping function provides visual distribution information. Its predator and prey fields are now linked to FishBase (www.fishbase.org), so that queries to one website access the other to provide ecologically relevant records of which cephalopods eat which fishes and vice versa. As the OBIS databases become linked through the EASy NetViewer software being developed for GMBIS (Tsontos and Kiefer, 2000; netviewer.usc.edu/web/), it will be possible to compare such interactions in time and space with major repositories of physical oceanographic data, such as sea temperature and colour for further ecological discrimination.

The demonstration projects for CoML are just beginning to yield field data, so it is premature to report results; however, Figure 1 indicates the present distribution of projects. Replication of these projects in areas of national interest around the world could provide a global census and a level of biological detail on marine biodiversity never previously achieved. It remains to be seen what additional approaches can improve coverage, but a significant advance is already clearly possible. The CoML's present thrust is to encourage adoption of these protocols through national and regional committees globally. This approach provides a clear opportunity to increase our systematic knowledge of cephalopods throughout the world in a wide range of habitats, and the incorporation into OBIS of the data collected provides a powerful tool for analysis in relation to both physical and biological elements of the world's oceans.

The ship-based demonstration projects are all in areas of traditional ICES interest, and there are excellent opportunities for ICES scientists to participate. In fact, such participation will likely be essential to their success. The telemetry projects are focused on the Pacific, but ICES scientists could play an important role in developing parallel Atlantic projects. Although the CoML is less focused on commercial species than most ICES science, commercial species do form an increasing component of global biodiversity. The CoML has already supported an ICES LMRC Workshop aimed at identifying areas where interests overlap and facilitating links between ICES projects and CoML projects. Clearly, the broad comparative approach the CoML fosters can provide new perspectives for ICES science. The accessible data that will reside in OBIS at the end of the CoML will be a valuable tool for all scientists interested marine ecosystems.

4. Discussion

The CoML program is aimed at recording what lives in the oceans in an accessible format that can be compared to what lived in the oceans historically and can contribute to predicting what will live in the oceans in the future. That such a bold venture is even possible is a result of new technologies, but the extent to which it succeeds will depend on the participation of marine scientists around the world. Participation by experts in all marine taxa will be needed to ensure that the results are accurate and useful. The scope of the program should provide opportunities to train new scientists with a mix of disciplines appropriate to 'the global village'. Many cephalopod scientists are already active participants because they recognize the unique opportunities that arise from systematic sampling of ocean regions where cephalopod are often a dominant fauna. Cephalopod biologists from around the world can continue to play leading roles as CoML activities expand in their regions.

The demonstration projects are testing efficient ways of quantitatively sampling marine organisms in a broad range of ocean habitats and providing data in formats that allow it to be recovered and compared. As these approaches are streamlined it will become possible to combine them with ongoing programs in all areas, so local collaborators are essential. Some of these approaches will likely become elements of routine biological monitoring after the CoML ends through interactions with the Partnership for Observation of the Global Ocean (www.oceanpartners.org) by coupling them to physical monitoring programs like ARGO and GOOS. Economical routine biological monitoring will be a powerful tool for fisheries management and can add a new dimension to fisheries science.

A key feature of the CoML program is accessibility. Information collected under CoML sponsorship must be made publicly accessible and the basic concept of OBIS as a network of databases is open access. Most scientists quickly recognize the advantages and power of allowing others access to their data in exchange for access to other's data, particular when tools for viewing and analysing them comparatively are available. However, fisheries data, which can be extremely valuable in analysing biodiversity, is not always accessible. ICES has a long history of dealing with such data and could play an important role in the CoML by helping to resolve this limitation.

The opportunities for cephalopod biologists include: (1) adding their collected biogeographic observations to a dynamic database where sophisticated new analyses will be possible, (2) developing and participating in programs for collecting and describing new species from unique habitats, (3) using advanced techniques to quantify cephalopods in these habitats and even development of molecular genetic approaches to cephalopod biodiversity (www.zoogene.org).

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Figure legend

Figure 1. Global distribution of the six planned and projected CoML demonstration projects. Details provided in the text.

Figure 1